TABLE

Comparison of heat transfer coefficient and pressure drop for the flat channel and surface feature geometries for 0.040 inch gap

	Gas		Liquid	
	Flat Channel	Surface features	Flat Channel	Surface features
Inlet Velocity (m/s)	0.47	0.47	0.60	0.60
Reynolds number	~1000	~1000	~1000	~1000
% increase in area		34%		34%
HTC (W/m2/K)	336	527	5174	12244
% HTC Improvement		44%		136%
Pressure Drop (psi)	0.0008	0.0011	0.07	0.09
% Pressure drop increase		40%		36%

In both cases, the increase in heat transfer coefficient is greater than the pressure drop increase per unit length. Further, it would be expected to decrease the microchannel length for the more efficient exchanger and thus further reducing the system pressure drop.

Example

Methane Combustion

[0261] Combustion of methane was modeled using a global one-step mechanism in which methane reacts with 2 oxygen molecules to form one molecule of CO_2 and 2 of water (equation 1). The rate of methane consumption was model and being first order in both methane and oxygen (equation 2). The activation energy estimated in a separate study and found to be 553,900 kJ/mol, the pre-exponential factor 1130 m^4/kgmol/s and the center temperature was 1098.2K.

Equation 1

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

Equation 2

$$r_{CH_4} = k_{CH_4} \exp\left(\frac{-E_a}{R}\left(\frac{1}{T} - \frac{1}{T_c}\right)\right) C_{CH_4} C_{O_2}$$

The specific objective of this example is to use a small CFD model to simulate a microchannel geometry with an isothermal temperature wall boundary condition to quantify combustion performance improvement in a design with surface features compared to a comparable design with flat walls (or no surface features).

[0262] The input conditions are given in the following Table

TABLE

Boundary conditions for the Pt-Re fuel lean combustion emissions clean-up channel CFD simulations.

Run	Units	Case 1 - 750° C.	Case 2 - 850° C.
inlet ppm CH4	(ppmv)	2500	2500
Inlet gas temperature	(° C.)	750	850

TABLE-continued

Boundary conditions for the Pt-Re fuel lean combustion emissions clean-up channel CFD simulations.

Run	Units	Case 1 - 750° C.	Case 2 - 850° C.
Outlet Pressure	(psig)	3.3	3.3
CH4 inlet flow	(kg/sec)	2.483E-07	2.483E-07
O2 inlet flow	(kg/sec)	5.181E-06	5.181E-06
N2 inlet flow	(kg/sec)	1.717E-04	1.717E-04

The experimental performance data with and without surface features is shown in FIG. **8**.

[0263] The model was run with boundary conditions listed in the table above. The pre-exponential constant for the combustion catalyst kinetics was modified until the model prediction for CH_4 conversion matched the experimental data at 750° C. both with and without surface features. The performance enhancement with surface features was quantified by taking ratios of the pre-exponential factor required in the model to match experimental performance with and without surface features. The surface feature enhancement factor was estimated at 750° C.

[0264] The methane conversion performance improvement factor with surface feature at 750° C. was 4.4×. That is to say, a catalyst disposed only on a flat wall would have to be 4.4 times as active at 750 to achieve the same performance as the catalyst disposed in the microchannel with surface features.

Assumptions and References

[0265] The geometry is a 0.058 inch gap channel, 0.16 inch wide, and 3.5 inch long

[0266] The surface feature pattern was SFG-1 on both top and bottom of the channel.

[0267] The lean combustion kinetics pre-exponential factor for the baseline case was 1129.3 and was represented as 1×. The experimental catalyst on the smooth or flat channel as measured in this experiment was much higher—a result from a modified formulation. The same catalyst formulation was used for both cases.

[0268] The pre-exponential factor was modified to match the CH_4 conversion for smooth channel at 750° C. The CH_4 conversion at 750° C. for the smooth channel was approximately 47% (see FIG. **1**). After matching the performance of smooth channel, the pre-exponential factor was changed to match the performance with surface features. The following table summarizes the results.

TABLE

Summary of CFD Model Analysis at 750° C.

	Smooth Channel	Surface Feature Channel
Pre-exponential factor lean Kinetics	191978	846960
CH_4 conversion		
Experimental	47.6%	58.9%
CFD	47.9%	59.5%